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Correlations of Scanning Multichannel Microwave Radiometer (SMMR) observations with snowpack properties of the Upper Colorado River Basin for Water Year 1986

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Abstract

For the Upper Colorado River Basin, the gridded 18 and 37 GHz brightness temperatures from the Scanning Multichannel Microwave Radiometer (SMMR) on the Nimbus-7 satellite and snowpack properties measured by the automatic, remote snow observation sites of the Soil Conservation Service (SNOTEL) provide unique time series data for passive microwave snow studies. Time series of the correlation coefficients using the SNOTEL data and a combination of the brightness temperatures from the ¼° latitude by ¼° longitude pixels that contain one or more of the 100 SNOTELs show that the correlations are generally greater than 0.8 and can attain values as great as 0.95. The correlations remain high until a basin-wide warming event occurs which produces liquid water in the snowpack that abruptly lowers the correlation. The envelopes of the correlations for the Utah and Wyoming snowpacks are significantly different than that for the Colorado pack.

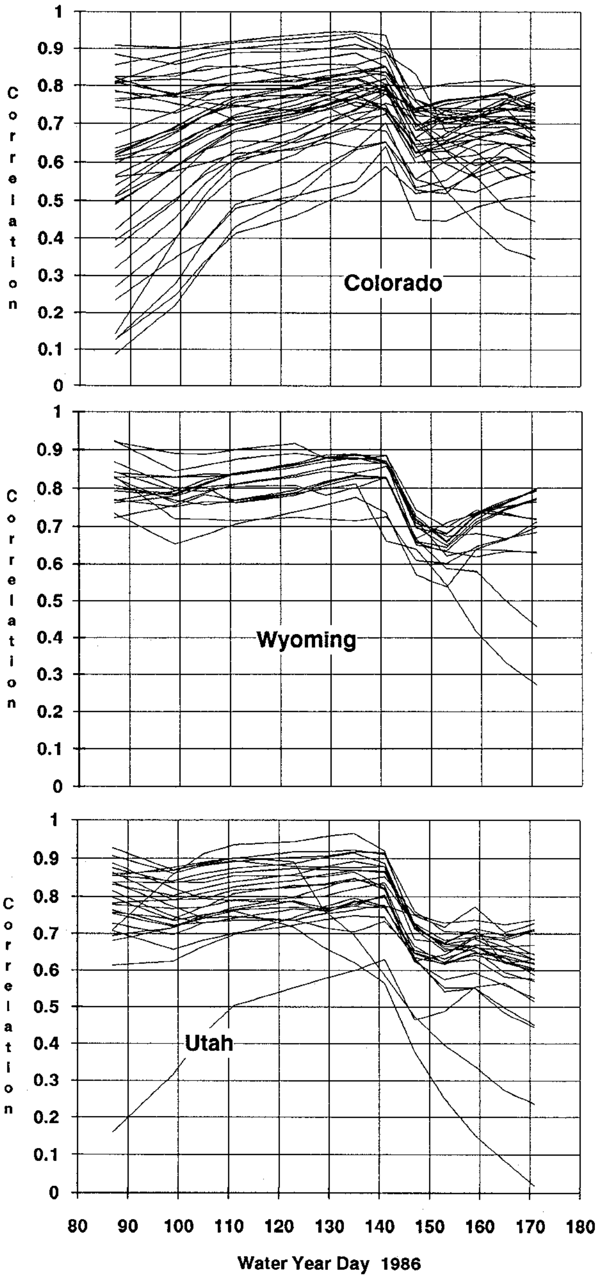

Figure 2. The time series of correlation for the three regions of the basin.

This abrupt basin-wide decrease in correlation occurs well before the occurrence of maximum snowpack water equivalence, which generally takes place at the end of March. This decline in the correlation resulted from warming and either rain or wet snow that produced liquid water in the snowpack. The SNOTEL records clearly show the warming event that produced liquid water in the snowpack, either from snowmelt or liquid precipitation. Figure 3 gives the temperature records from four SNOTELs, one each from the Wyoming and Utah regions and two from the Colorado regions, one at the north and one at the south end. Table 1 gives the names, locations and elevations of these four representative SNOTELs which are among the highest of the SNOTELs in each region, and hence would show the coldest temperatures. Temperature records from other sites, at lower elevations, show similar behavior with warmer temperatures.

Table 1
Selected High-Altitude SNOTEL Sites

Site	Latitude	Longitude	Elevation
1 Elkhart Park	43.00°	109.75°	2865 m
2 Daniels-Strawberry	40.30°	111.25°	2438 m
3 Tower	40.55°	106.67°	3109 m
4 Red Mountain Pass	37.88°	107.70°	3380 m

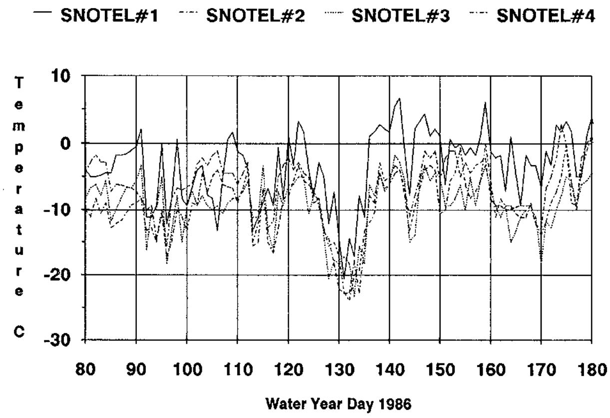

Figure 3. The temperature records from the four SNOTELS in Table 1.

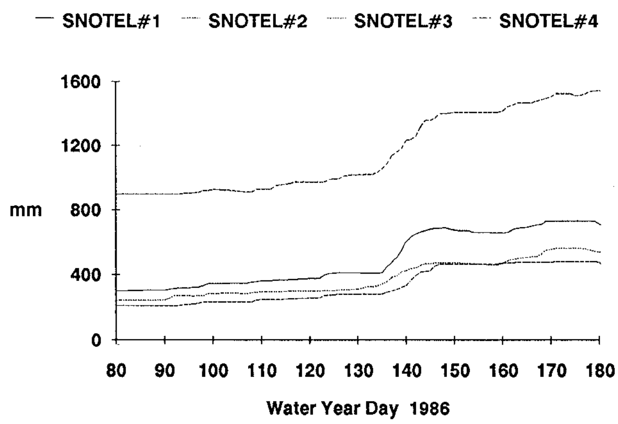

Figure 4. The snow water equivalent records form the four SNOTELS in Table 1.

4. Summary

The correlations between the SMMR and SNOTEL observations for the Wyoming and Utah snowpacks in the Upper Colorado River Basin for Water Year 1986 are uniformly high for all the mesoscale (625 km^2) pixel areas, 16 in Wyoming and 26 in Utah, with the exception of one, until the warming event that occurred on day 141. The envelopes of these correlation curves maintain a relatively constant width of 0.2 with slowly improving correlations as the snow accumulation season progresses. Considering that these calculations implicitly assume that one

SNOTEL is representative of an entire pixel, without including the dependence of snow depth on elevation and aspect, these high correlations are surprising and most encouraging.

The case for the Colorado snowpacks is not as clear. The correlations at the start of the snow accumulation season range all the way from 0.1 to 0.9, with a majority falling between 0.5 and 0.9. Although the correlations for all mesoscale pixel areas, 39 in this case, increases as the accumulation proceeds, the width of the envelope of the family of correlation curves shrinks to only 0.4 by water year day 141. There are a number of factors that may be responsible for the observed behavior. First, the topography of the Colorado pixels have a greater range in altitude, and pixels with significant areas of low altitude may not be completely snow-covered early in the snow season. Thus, as the accumulation season progresses a greater percentage of a pixel becomes snow-covered, giving progressively higher SNOTEL/SMMR correlations. Also, the greater range in topography for the Colorado pixels will produce a more variable snowpack within a pixel. Second, the Colorado snowpacks have consistently smaller grain size, usually no greater than 1 to 2 mm, than the Wyoming and Utah snowpacks, which, as a result of depth hoar formation, can be as large as 5 to 6 mm. These large grain size have a dramatic effect on the SMMR radiances. Third, the vegetation may be different in each region and hence would require correction for each mesoscale pixel area.

In conclusion, this study found high correlation of mesoscale passive microwave observations and point snow observations, in which many complicating factors have not yet been included. This fact compels us to believe that satellite passive microwave observations of snowpacks may indeed lead to improved synoptic, sequential SWE estimates for large, topographically complex, and inaccessible snowpacks.

5. References

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